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TECHNICAL NOTE

Carl N. Stephan,[1] *Ph.D.; Rachel M. Norris,*[1] *Ph.D.; and Maciej Henneberg,*[1] *D.Sc.*

Does Sexual Dimorphism in Facial Soft Tissue Depths Justify Sex Distinction in Craniofacial Identification?

ABSTRACT: Separation of male and female soft tissue depths into discrete groups for craniofacial identification implies that males and females differ enough from each other, with respect to this application, for this distinction to be useful. In this study, previously published soft tissue depth data were analyzed for sex separation. It was found that the variation within each sex was large while the variation between the sexes was small. Often the value of two standard deviations of the measurement for either sex was larger than the difference displayed between the means of each sex. Furthermore, opposite sex overlap in regions defined to be close to the male or female mean were found to be large and the amount of variance explained by sex was small (less than 6% on average). These results indicate that while male and female means at single craniofacial landmarks may differ slightly, and even at statistically significant levels, individual male and female soft tissue depths are often the same or very similar. On average, soft tissue depths of the face do display some sexual dimorphism but it is not marked and of little practical meaning for craniofacial identification where a single individual must be independently considered. Thus, there is little use in separate reporting of data for males and females and data should be combined to increase sample sizes.

KEYWORDS: forensic science, facial approximation, superimposition, variance, soft tissue thickness

Sex is the characteristic of being male or female, and is commonly used for categorical assortment of animals, including humans, into two groups. However, sex groups may not represent actual human variation well for not all individuals can be neatly classified as male or female based on current sex markers (1,2). For example, not all individuals have sex chromosome combinations of either XX or XY (1), some individuals show sex reversal even when they possess sex specific chromosomes (i.e., 46 XY or 46 XX) (1), and sex reversal may occur even if *SRY* (sex determining region of the Y chromosome) follows the "normal" pattern: present in males (46 XY SRY^+) and absent in females (46 XX SRY^-) (2). Despite this imprecision, the expression of sexual characteristics or sexual dimorphism, has been accepted as a major factor in determining the soft tissue thicknesses of the human face for craniofacial identification (see e.g., 3,4). However, there is some debate whether sex is a useful factor for determining soft tissue depth values as used for forensic identification of skulls (5).

The largest inventory of soft tissue depth studies collected so far on the human face has included more than 50 studies, and where males and females have been measured the data are always classified by sex (Stephan and Simpson, personal communication). For most landmarks, the sexes do appear to differ on average (see examples given in Table 1 and Fig. 1 for "Caucasoid" subjects). In some samples, means at *some* landmarks are found to differ at statistically significant levels (3,4,6) and larger sampled studies (see e.g., 4) tend to report more statistically significant differences than their smaller sampled counterparts (see e.g., 6). However, the difference between the means of human soft tissue depths is small, often being less than 2 mm (3,4,6–8), despite statistical significance in some instances. Table 1 gives examples of the relative size of the difference between the means of the sexes for three recent studies on "Caucasoid" subjects. The average difference, across all landmarks between the sexes, generally seems to be *much* less than 20%, although it is highly varied. Note that there are five instances out of 21 in the Wilkinson study (3) where the soft tissue depths are identical between the sexes (Table 1).

It is possible that method error accounts for some (perhaps even all) of the differences between the sexes, yet this is difficult to evaluate conclusively as the authors who measure soft tissue depths infrequently report measurement errors. Simpson and Henneberg (6), report total method errors (i.e., intra- and inter-investigator errors combined) as large as 54.5%, but generally in the vicinity of 1–2 mm. Leaving measurement error aside, the question arises: is the difference between the mean soft tissue depths of males and females large enough to warrant sex classification of the data? The answer to this question does not necessarily depend on results of statistical significance tests as often emphasized in the literature (see e.g., 3,4,6), but more fundamentally upon within group variation and the context in which the question is asked—in the case considered here, anthropological identification, where emphasis is placed on the identification of an individual (9).

Findings of statistically significant differences between means, with respect to any variable, may not be helpful for ascertaining group discreteness since statistical significance depends on sample sizes and the criteria set for significance determination (i.e., the

[1] Department of Anatomical Sciences, The University of Adelaide, Australia, 5005.

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TABLE 1—*Mean, variance and overlap analysis for data reported by three recent studies (3,4,7) on three different subject cohorts (sub-adult, young adult and older adult). Calculations of overlap are based on standard normal probabilities. Overlaps have not been calculated for landmarks where the means between the sexes are not found to differ. Data have been italicized for landmarks where males have smaller means than females. The same numbers of decimal places are reported for means and standard deviations as reported in the original publications.*

Wilkinson (2002); white subadults; 13–14 years; A-mode ultrasound

Landmark	Female mean $n = 21$	Female s	Male mean $n = 23$	Male s	Diff. betw. means relative to smallest mean	% F overlap within M 95% range	% M overlap within F 95% range	% F overlap beyond M 25th (*or 75th*) percentile	% M overlap beyond F 75th (*or 25th*) percentile	r^2
Forehead (1)	5.0	0.88	5.0	0.89	0.00					
Glabella (2)	5.2	0.86	5.2	0.89	0.00					
Nasion (3)	4.7	0.95	5.2	0.89	0.11	89	95	54	58	0.07
Nasal bone (4)	2.2	0.61	2.4	0.84	0.09	98	84	73	58	0.02
Mid-philtrum (5)	9.6	2.14	10.3	2.20	0.07	95	94	66	62	0.03
Upper lip bord. (6)	9.2	1.66	10.6	1.78	0.15	90	86	46	42	0.15
Lower lip bord. (7)	10.5	1.74	12.2	2.13	0.16	93	78	42	38	0.17
Labiomental groove (8)	*9.4*	*2.29*	*8.9*	*2.09*	*0.06*	*93*	*97*	*66*	*69*	*0.01*
Mental tubercle (9)	8.9	1.94	10.1	1.98	0.13	92	92	54	54	0.09
Gnathion (10)	6.0	1.22	6.0	0.94	0.00					
Lateral forehead (11)	5.4	0.93	5.4	0.95	0.00					
Mid supra orbital (12)	6.5	0.91	6.6	0.98	0.02	97	94	73	69	0.00
Mid infra orbital (13)	7.3	1.20	8.3	1.30	0.14	90	86	46	42	0.15
Lateral nose (14)	5.9	1.25	6.4	1.79	0.08	99	82	73	58	0.03
Mid lateral orbit (15)	*7.4*	*1.15*	*7.1*	*1.12*	*0.04*	*95*	*95*	*66*	*66*	*0.02*
Zygomatic attach. (16)	10.2	1.81	10.7	2.48	0.05	99	86	73	62	0.01
Upper first molar (17)	*16.2*	*3.15*	*14.7*	*3.31*	*0.10*	*95*	*92*	*58*	*58*	*0.06*
Lower first molar (18)	14.5	2.84	14.6	2.28	0.01	90	98	69	79	0.00
Mid mand. angle (19)	9.1	1.87	9.1	1.84	0.00					
Mid zygomatic arch (20)	7.9	1.87	8.4	1.63	0.06	91	98	62	69	0.02
Mid masseter muscle (21)	16.6	4.97	17.4	4.94	0.05	94	96	69	69	0.01
				Average	0.06	94	91	62	60	0.05

Manhein et al. (2000); white adults; 19–34 years; B-mode ultrasound

Landmark	Female mean $n = 52$	Female s	Male mean $n =$ about 28	Male s	Diff. betw. means relative to smallest mean	% F overlap within M 95% range	% M overlap within F 95% range	% F overlap beyond M 25th (*or 75th*) percentile	% M overlap beyond F 75th (*or 25th*) percentile	r^2
Glabella (1)	4.8	0.95	5.0	0.67	0.04	83	99	62	76	0.01
Nasion (2)	5.5	1.16	6.0	1.12	0.09	92	94	58	58	0.02
End of nasals (3)	1.8	0.63	1.9	0.45	0.06	85	100	62	76	0.00
Lateral nostril (4)	*8.6*	*1.99*	*7.5*	*1.90*	*0.15*	*91*	*93*	*54*	*54*	*0.04*
Mid philtrum (5)	9.1	1.69	11.9	2.24	0.31	84	62	21	24	0.21
Chin lip fold (6)	10.3	1.55	11.1	1.85	0.08	97	86	62	54	0.03
Mental eminence (7)	9.2	2.08	10.0	2.77	0.09	99	84	69	58	0.01
Beneath chin (8)	6.0	1.45	7.2	1.73	0.20	95	83	50	46	0.07
Superior eye orbit (9)	*5.7*	*1.04*	*5.3*	*1.25*	*0.08*	*98*	*88*	*66*	*58*	*0.02*
Inferior eye orbit (10)	*6.1*	*1.05*	*5.8*	*1.58*	*0.05*	*100*	*79*	*76*	*62*	*0.01*
Supracanine (11)	9.3	1.74	11.9	2.65	0.28	95	61	31	31	0.15
Subcanine (12)	9.4	1.56	11.5	2.17	0.22	92	68	34	31	0.14
Supra M2 (13)	26.3	4.94	28.5	4.69	0.08	92	95	58	58	0.02
Lower cheek (14)	23.4	4.53	25.1	4.15	0.07	92	96	58	62	0.02
Mid mandible (15)	13.7	3.25	14.8	4.48	0.08	99	84	73	58	0.01
Lateral eye orbit (16)	*4.7*	*0.88*	*4.2*	*0.79*	*0.12*	*87*	*95*	*50*	*54*	*0.04*
Zygomatic (17)	*9.3*	*1.70*	*7.8*	*2.38*	*0.19*	*97*	*77*	*54*	*42*	*0.07*
Gonion (18)	17.4	3.70	20.0	4.27	0.15	95	85	54	50	0.05
Root of zygoma (19)	7.4	2.07	7.8	2.29	0.05	97	93	69	66	0.00
				Average	0.13	93	85	56	54	0.05

Simpson and Henneberg (2002); white adults; 52–101 years; needle piercing

Landmark	Female mean $n =$ about 18	Female s	Male mean $n =$ about 13	Male s	Diff. betw. means relative to smallest mean	% F overlap within M 95% range	% M overlap within F 95% range	% F overlap beyond M 25th (*or 75th*) percentile	% M overlap beyond F 75th (*or 25th*) percentile	r^2
Metopion (1)	4.00	1.43	5.50	1.88	0.38	95	75	42	38	0.14
Superciliare (2)	6.82	1.93	8.17	2.37	0.20	97	83	54	50	0.07
Glabella (3)	5.83	1.37	6.69	1.77	0.15	98	82	58	50	0.05
Nasion (4)	5.32	1.19	6.69	1.41	0.20	88	69	34	34	0.17
Rhinion (5)	2.59	0.99	3.04	1.03	0.17	94	92	58	58	0.04
Zygion (6)	9.07	2.83	10.88	4.90	0.20	100	72	69	50	0.03
Maxilla (7)	15.64	4.34	17.42	3.68	0.11	88	97	58	62	0.03
Alare (8)	11.40	2.59	11.44	3.36	0.00	100	88	82	69	0.00
Supracanine (9)	7.56	2.32	8.81	2.68	0.17	96	89	58	54	0.04
Subnasale (10)	10.89	3.27	13.46	2.97	0.24	84	90	42	46	0.10
Philtrum (11)	8.31	2.54	10.15	3.29	0.22	97	82	54	50	0.07
Upper lip (12)	6.78	1.94	8.58	2.63	0.27	96	78	50	42	0.10
Lower lip (13)	7.58	2.05	9.62	2.23	0.21	88	91	38	38	0.14
Chin fissure (14)	9.79	2.44	11.08	2.47	0.13	93	92	54	54	0.05
Pogonion (15)	*8.89*	*2.71*	*8.04*	*2.71*	*0.11*	*95*	*95*	*66*	*66*	*0.02*
Gnation (16)	6.89	2.20	7.36	2.68	0.07	99	89	73	66	0.01
Gonion (17)	13.61	5.22	18.52	10.60	0.36	100	61	66	46	0.06
Body (18)	12.13	5.11	12.21	4.85	0.01	95	96	73	76	0.00
Border (19)	9.87	3.73	12.47	7.13	0.26	100	68	73	50	0.03
Ramus (20)	17.60	3.73	21.04	4.73	0.20	95	78	54	42	0.10
				Average	0.18	95	83	58	52	0.06

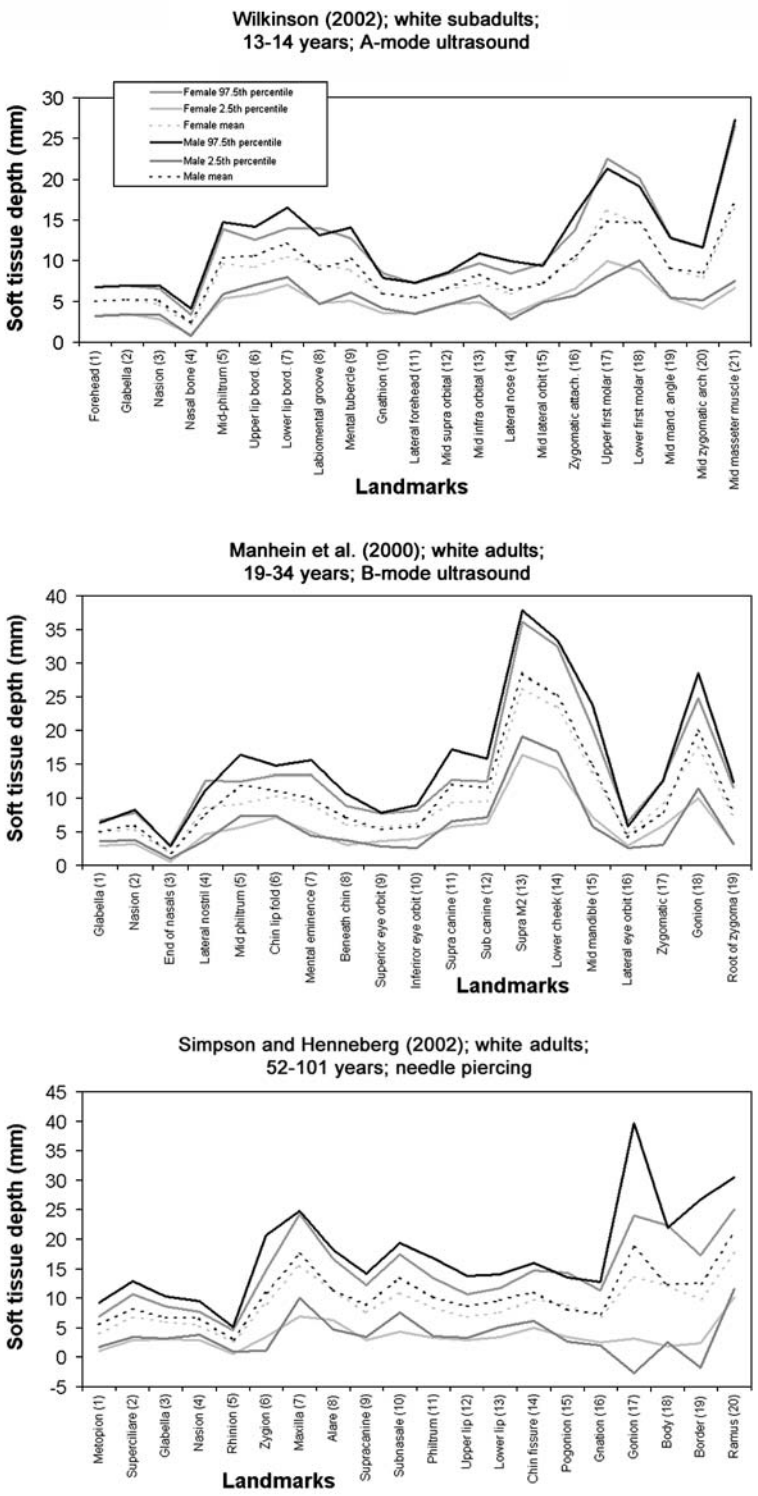

FIG. 1—*Ninety-five percent confidence intervals and means for male and female soft tissue depth measurements. The smallest degree of overlap is found at midphiltrum for the Manhein et al. (2000) study (see Table 1). The figure is derived from calculations that assume normality of data.*

p value). Any difference, even an extremely small one, will be statistically significant when "large" samples or less rigorous criteria for type I error are used (10,11). Furthermore, the p value does not measure the strength of an effect, but rather the strength of evidence of *some effect* (10). Thus, when analyzing the degree of separation between groups it is important to consider not only statistical significance but also the variance of each group, the overlap between distributions, and the practical meaning of any differences (10,12,13).

Like other parameters used by forensic anthropologists, soft tissue depths should be subject to an appropriate analysis of variation before it is concluded that statistically significant differences between the means justify classification of the data by sex. Despite statistically significant differences between the means, variation

within each sex group may be large making it impossible to tell the majority of male and female individuals apart on a case-by-case basis (5). Such a scenario would render sex classification of soft tissue depth data and use of sex specific means meaningless for craniofacial identification as many individual males may share identical or very similar values to many individual females and vice versa. Despite this issue being raised by Maat (5), more recent soft tissue depth studies (see e.g., 3,4,6,8) have continued to report sex-categorized data without appropriate justifications. This study further examines sex categorization, using recently published soft tissue depth data by Manhein et al. (4), Simpson and Henneberg (6), and Wilkinson (3). Variances are analyzed in a univariate manner using an approach similar to, but more comprehensive than, that of Maat (5).

Methods and Results

Table 1 summarizes the means and standard deviations for sex specific groups from several different but recent studies (3,4,6), which concern subject cohorts that differ by age. This table demonstrates that means of many soft tissue values for males are consistently larger than the means for females, but there are exceptions (see italicized landmarks, Table 1). Comparison of the means for each landmark to the range about the mean including 95% of data (2.5th percentile to the 97.5th percentile—assuming a normal distribution, which is assumed if means are employed) shows that both sex means always fall within the 95% ranges of the opposite sex group, no matter which study is considered (Fig. 1). Moreover, it can be seen that the majority of means fall within the range of one standard deviation about the mean of the opposite sex group (Table 1). Female data appear to display less variability than the male data (see Fig. 1 or Table 1) and it is also apparent that data at some landmarks are not normally distributed (the 2.5th percentile falls below zero Fig. 1). However, so that published means and standard deviations could be commented upon here we continue the assumption made in the literature that the data tend to normal distributions. Note that some other publications indicate that the distributions of some soft tissue measurements are skewed (e.g., measurements at zygion (6,14), labrale superius (6) and mid-mandibular border (6)), or report nonparametric statistics (3), yet these studies continue to generate arithmetic means. Whilst ignored here, this lack of precision needs to be addressed in future research.

The large within group variance relative to the differences observed between the means of males and females can be further highlighted by calculating the percentage of overlap of the opposite sex group in each of the sex specific 95% data ranges (Table 1). Figure 1 and Table 1 demonstrate that the overlap is large for males and females, but in general, slightly more female data tend to overlap with the male data. In many instances, 90% or more of individuals can be seen to fall within the 95% range of the opposite sex (Fig. 1 and Table 1). This supports observations by Maat (5) and indicates that sex differences in soft tissue depths are not large.

Opposite group overlap in 95% confidence ranges does not appear to be ideal for determining the usefulness of sex specific soft tissue depth means however, as the means are used to represent the most-dense data in each distribution. That is, more data tend to cluster close to the mean while fewer data are found in the tails of the distribution making it more likely that most of the sample falls closer to the mean rather than further away. Thus, when soft tissue depth distributions of the sexes overlap, a measure of the percentage of female data falling in a range close to the male mean will give a better indication of the usefulness of the male mean, and vice versa for females, rather than the general percentage of overlap of opposite sex data in the 95% data range about the male or female mean. This approach is also favorable in comparison to other methods (see e.g., 13,15–17) that measure the exact degree of overlap between distribution curves but not the total proportion of data from different groups sharing a common range. To make such a comparison however, some measure of "closeness" of data to each mean needs to be defined.

When dealing with continuous data that are normally distributed there will always be a gradual or continuous degree of increasing distance from the mean with increasing or decreasing z scores, but for an objective categorical decision of "close to the mean" it would seem that a 50% cutoff, relative to the group as a whole, is appropriate. Thus, a range incorporating 25% of the most-dense data on either side of the mean (equal to the "shortest half" of the normal distribution (18); which can be represented by the 25th and 75th percentiles or z scores of ± 0.67) can be used. Note that this is not a very strict criterion for the identification of individuals, as means will not closely represent 50% of the data in any group. This criterion minimizes, however, the chance of overlap between the sexes because the range about the mean in each group is less than if higher percentages were used (compare for example, the 25% criterion to the 47.5% criterion used above or by Maat (5)). Thus a 50% criterion is a very lenient test if "separate" groups are to be established.

If the means of two groups differ (i.e., between males and females), and overlap occurs between the distributions of these groups (as it does for all facial soft tissue depths), then the larger of the two means will most closely represent data from which that mean was generated, which fall above the 50th percentile of that group (i.e., above the mean and towards the right tail of the distribution), in contrast to the smaller mean of the other group. Consequently, the 75th percentile used to define closeness of data to the larger mean can be ignored. Similarly, since the smaller mean more closely represents the data from which the mean was generated and which fall below the 50th percentile of this group, than the larger mean of the other group, the 25th percentile can be ignored for the data of the group with the smaller mean. Thus, when considering the means of two normally distributed samples that differ from each other, but whose distributions overlap, each mean can be considered to closely represent 75% of their respective data, and poorly represent 25% of their data. It is, therefore, of interest to know two things: (i) what percentage of the group with the smaller mean (usually the females) falls above the 25th percentile of the group with the larger mean (usually the males); and (ii) what percentage of the group with the larger mean (usually the males) falls below the 75th percentile of the group with the smaller mean (usually the females). Table 1 reports actual degrees of overlap for males and females for these two scenarios using published data from the literature. Figure 2 displays three examples as distribution plots. It is clearly apparent from Table 1 that the means of both sexes often fall in the range defined to be close to the opposite sex mean because more than 50% of the data overlap. In many cases the mean of the opposite sex group falls within the range defined to be close to the other sex mean (also see Fig. 2). This suggests that the differences between the means of each sex, relative to the distribution of each sex, are not large. Out of the 21 landmarks measured by Wilkinson in only three instances did the male and female overlaps both fall below 50%. For the Manhein and colleagues study there were again three instances out of 19 landmarks where overlap fell below 50% for both males and females at any one landmark. In the Simpson and Henneberg study, which displayed the biggest separation between the sexes in general (Fig. 1), there where four out of 20 landmarks where the overlap for both sexes fell below

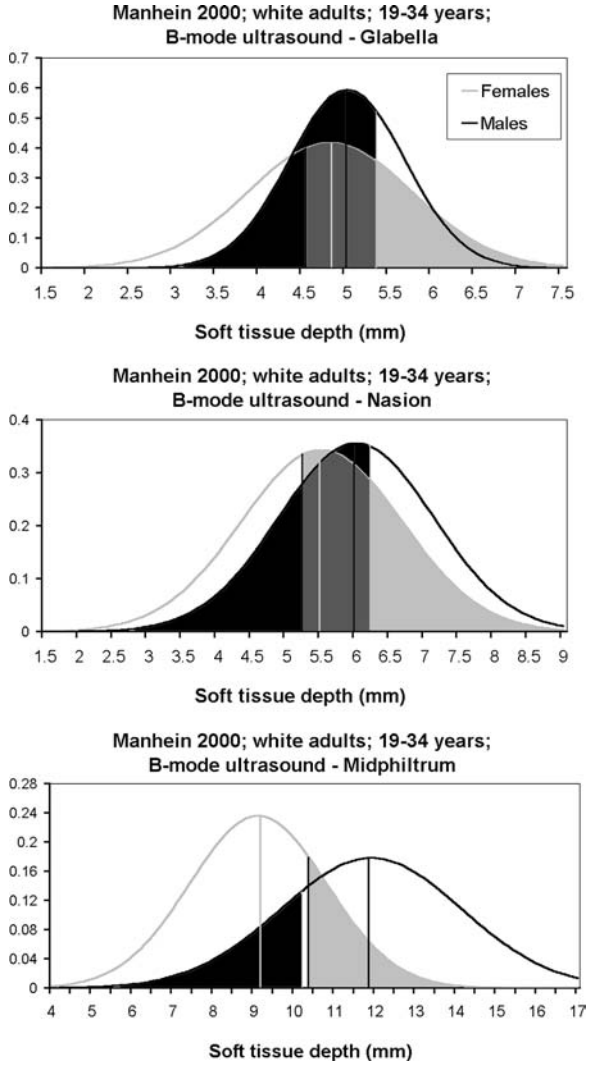

FIG. 2—*Examples of opposite sex overlap in ranges defined to be close to each sex specific mean, i.e., beyond the 25th or 75th percentile for each sex. Curves have been calculated from the means and standard deviations reported by Manhein et al. (2000), assuming normality of data, and using the equation:*

$$\frac{1}{s\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-m}{s}\right)^2}$$

Where:

x is any soft tissue depth value within the sample
m is the estimate of the population mean based on the sample mean
s is the estimate of the population standard deviation based on the sample standard deviation

The example at glabella illustrates one of the largest, but not the highest, degrees of overlap observed in Table 1 (males = 76%, females = 62%). The example at nasion illustrates the average overlap observed for all landmarks presented in Table 1 (58% for both males and females). The example at midphiltrum illustrates the single lowest degree of overlap displayed in Table 1, however this patterning was rare (males = 24%, females = 21%).

50%. Only one landmark, midphiltrum, described by Manhein et al. (4), showed less than 25% overlap for males and females (Table 1 and Fig. 2). Slightly more female data could be found in the male range, as reported for 95% data ranges, but on average over 58% of opposite sex data could be found in the range defined to be close to either of the sex specific means (see Table 1 for actual values and Fig. 2 for visual representation of high, average and low degrees of overlap). This is a large percentage considering that it is respective to 75%—the maximum amount of data that the means of a group are deemed to closely represent by definition. Note that if criteria for "closeness" were lowered to allow more data to closely represent the mean of either group, overlap would increase.

These findings indicate that the variation within the groups is large relative to the difference between the groups. This is also demonstrated by the r^2 values presented in Table 1, which show that sex explains very little (<6% on average) of the variation in soft tissue depths between individuals. It, therefore, seems of little use to classify the human facial soft tissue depth data by sex, at least for craniofacial identification purposes, because a very large proportion of male and female individuals share identical values causing sex specific means to represent, not only large proportions of their respective group well, but also large proportions (often more than 50%) of the opposite sex group.

This analysis is based on comparisons of means and variances reported at a number of landmarks by a number of different studies. Unfortunately, we cannot present evaluations from all studies reported in the literature due to space restrictions. Instead we have described three recent studies by different authors of different subject cohorts, and have demonstrated consistency across these studies. We have found these patterns to be highly consistent and suggest that if readers need further clarification they should calculate the parameters presented in Table 1 for other studies not reported here.

Although we attempted to conduct multivariate tests (factor analysis, principal components analysis, and discriminant function analysis) in addition to the univariate tests reported here, these tests were unsuccessful. Few authors made their samples of raw data available for the analysis (see acknowledgements for those that did) and incompatable landmarks and missing values made tests problematic. Multivariate analysis remains the domain of future investigations, however, results of this study suggest that if any relationships exist between different landmarks their effects are probably still small and overshadowed by measurement error.

Conclusions

Analyses of previously published soft tissue depth data for males and females reveal no marked sex grouping because the variance within each sex is large, and the variance between the sexes is small. The amount of variance explained between individuals by sex (about 6% on average) is even smaller than the amount explained by craniometrics, which is also small (median of 12%, see Table 8 (6)). There are too many individuals who share identical soft tissue depth values between the male and female groups for sex specific means to be considered useful in craniofacial identification. Even though means at individual landmarks may differ at statistically significant levels between the sexes (see e.g., 3,4,6–8) the means often accurately represent many members of the opposite sex as well as they represent many members of the sex from which they were derived. Thus, the clustering of male and female soft tissue depths is not strong enough to justify the use of sex specific soft tissue depth means in attempts to identify single individuals. These findings reiterate conclusions made by Maat (5) that sex specific averages offer little benefit to craniofacial identification methods. These results suggest that it may be difficult to find uniform and robust predictors of soft tissue depths since generic variables like sex are not sufficient. This clearly indicates that more detailed analyses of the soft tissue relationships to the skull are required if soft tissue depths which have some specific applicability to individuals, or certain samples, are to be described.

Results of this study, like findings by Maat (5), also suggest that sex specific means previously reported in the literature can be combined. This will simplify soft tissue depth data, increase sample sizes, and will not compromise the accuracy of current soft tissue thickness averages in forensic casework. Combining data of both sexes is further supported by findings that errors in measurement (and potentially application) of soft tissue depths subsume most of the difference (<1 or 2 mm) observed between the sexes in many cases (6,19). This further highlights the dubious nature of sex specific classification of soft tissue depth means in craniofacial identification practice.

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Additional information and reprint requests:
Carl N. Stephan, Ph.D.
Department of Anatomical Sciences
University of Adelaide
Adelaide 5005 Australia
E-mail: carl.stephan@adelaide.edu.au